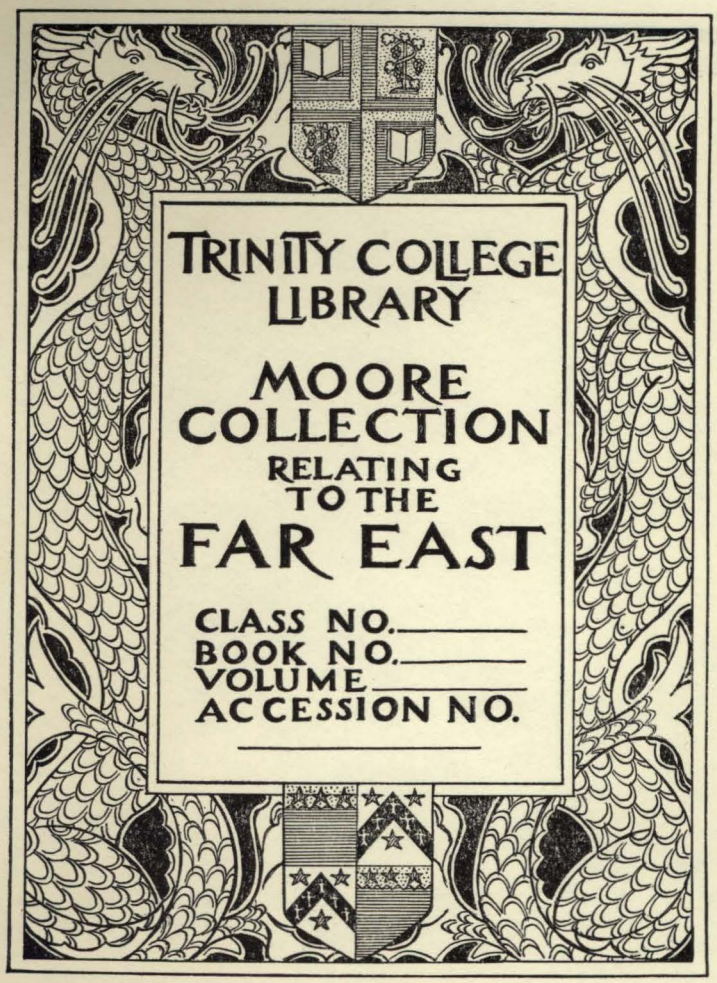
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THE YELLOW EMPEROR'S SOUTH-POINTING CHARIOT

BY
GEORGE LANCHESTER

WITH A NOTE BY
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THE YELLOW EMPEROR'S SOUTH-POINTING CHARIOT*

By George Lanchester

In 1932 my friend Dr. J. B. Kramer, an eminent electrical engineer, delivered a lecture on the "History of Magnetism", in the preparation of which he set himself to show that magnetism was not, as has been maintained by many writers, discovered by the Chinese. I think it worth while to quote the following passage from his lecture:

> "Quite a host of writers in early times as well as of late claim that the Chinese were the first who had knowledge of magnetism. The claim goes even to the extent that the Chinese applied, over 4,500 years ago, a magnetized needle as a compass to guide their land chariots across the vast steppes leading south.
>
> "To them the south was more important than the north, by reason that where the sun stood highest there was the life-giving centre."

He goes on to say—

> "Where are the manuscripts in which the Chinese lay claim to the honour of having discovered the magnet? There are none, and there never existed any writings by the Chinese claiming for themselves that discovery."

In the course of his researches when compiling his lecture he visited the British Museum, where, by the courtesy of Mr. Lionel Giles, Librarian of the Oriental Library, he was able to study Dr. Herbert A. Giles's historic work, *Adversaria Sinica* (Book No. 11853 S.), in which he found evidence that that remarkable Chinese invention, the South-Pointing Chariot, was a mechanical device and not a magnetic compass.

On pages 106-114 in Dr. Giles's book appear the following two legends:

(1) "The Chinese Emperor, Huang-ti, 2698-2598 B.C., fought at Cho-Lu against the rebellious Prince Ch'ih-yu.

"The latter raised a great mist as a screen to their movements, in consequence of which the Yellow Emperor's troops lost their way and the sight of the enemy.

"Huang-ti constructed a chariot upon which was mounted a prominent figure with arm outstretched, and which always pointed south whatever might be the direction taken by the chariot. By these South-Pointing Chariots Huang-ti extricated his soldiers, led them to victory, and put the rebellious Prince to death."

(2) "When the Ambassadors of the Yüeh-Shang nation came with tribute from Cochin-China in the days of Ch'êng of the Chou dynasty, 1122-255 B.C., the Chinese Minister of State—Chou Kung—gave the envoys a South-Pointing Chariot (called Chih-Nan), as they were afraid that they would not find their way back through the flat unidentifiable country which they had to traverse without being lost."

Later in his research Dr. Giles discovered a description (it can hardly be termed a specification) of the South-Pointing Chariots, which reads as follows:

> "Above the Chariot, which was mounted with a single pole for two horses, was fitted a double roof, and above that a wooden figure of an Immortal or Angel stretching out an arm which pointed South."

The mechanism of the chariot was built to the following specification:

> "There are 9 great and small wheels, 120 cogs—
>
> 2 Wheels 6 feet high, 18 feet circumference.
>
> 2 Vertical child (small) or subordinate wheels attached to the above, 2 feet 4 inches in diameter, 7·4 feet in circumference, 24 cogs to each wheel, 3 inches apart.

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* Lecture delivered to the China Society on February 3, 1947. Mr. A. L. Hetherington, C.B.E., presided.

2 Small vertical wheels at end of pole below the transverse wood (? roof) of 3 inches in diameter with an iron rod piercing them.

1 Small horizontal wheel on the left, 1 foot 2 inches in diameter, 12 cogs.

1 Small horizontal wheel on the right and one large horizontal wheel in the middle, 4·8 feet diameter, that is 14·4 feet in circumference, 48 cogs, 3 inches apart.

1 Rod through the middle, 8 feet high, 3 inches in diameter, on the top of which is carried a carved wooden figure, which, when the Chariot is in motion, points to the south.

"If you turn to the east (when going south), the child wheel attached to the foot wheel on the right of the pole will turn round 12 cogs and the small horizontal wheel attached to the right will turn once, and cause the middle large horizontal wheel to turn round a quarter, or twelve cogs, so that if the car goes east the wooden figure would be interlocked and point south. The same thing would happen going north, east or west."

This specification, although unintelligible, confirmed my friend's contention that the magnetic compass was not discovered by the Chinese, but it also proved that a Chinese engineer had invented a most ingenious mechanism, the details of which have been lost for many centuries.

Dr. Kramer, having discovered the specification recorded by Dr. H. A. Giles, submitted to me, as a mechanical engineer, the problem of elucidating the specification and reconstructing the South-Pointing Chariot.

I could find nothing in the specification to give any clue as to how the mechanism operated, and, as even the arithmetic of gear-wheel sizes and numbers of teeth was inaccurate, I decided to visit the British Museum to try and find some other clues. In May, 1932, Mr. Lionel Giles kindly gave me access to the original specification in *Adversaria Sinica*, and also informed me that other engineers had endeavoured to find a solution.

He placed at my disposal some notes—one by the late Professor Bertram Hopkinson, of Cambridge (he was Professor of Mechanical Engineering and an authority on internal combustion engines and a well-known balloonist); and the other by the Rev. A. C. Moule, of Cambridge.

Professor Hopkinson expressed the view, with which I concur, that the specification gave no indication of the principle of the South-Pointing Chariot and that a working model could not be constructed from it.

Mr. Moule suggested a solution which I examined. If I remember rightly, his interpretation assumes that the pointing figure is placed and held statically pointing in the pre-determined direction and the chariot is then drawn along in a straight course. When it is desired to turn, the chariot is stopped and a gear-wheel is engaged either with the right or left road wheel according to the direction of the turn desired.

The engaged gear then propels the pointing figure rotationally during the process of turning, and at the end of the turn the gear is disengaged and the figure is again fixed statically until it becomes necessary to make a further deviation.

Now apart from the clumsiness of the method it is a fallacy to imagine that a traveller can maintain a perfectly straight course, whether on foot, either riding or leading a horse, or on a vehicle.

Anyone who has walked across a meadow where his track can be observed by the disturbance of the grass knows how devious his track may be. Every motorist knows that on a dark night, or in a fog, or smoke screen, one can turn very considerably "off course" without being aware of it.

So I "came out by that same door wherein I went", and, thrown back on my own resources, I decided to ignore the specification and work out the problem from its elementary principles.

The question came to mind as to why the specification was so unintelligible. There are two possible reasons. On the one hand the translator may not have been suffi-

ciently well versed in engineering knowledge to interpret correctly the original specification.

Alternatively, and I am inclined to think more probably, the holder of the secret may have deliberately deceived his non-technical master by withholding the essential information and clothing the specification with unessential and even false detail in order to preserve the secret for himself.

Throughout all time, until comparatively recent years, such secrecy has been a stumbling-block to progress, and there are numerous instances, both in arts and crafts, of a reluctance to make information available to the community, retaining secrecy for the benefit or personal profit of the individual.

Apparently Dr. Giles discovered the specification after he had discovered the legends of its use. In pages 219-220 of *Adversaria Sinica* he quotes:

> "Before Yen-Su's time the secret has been lost from the early B.C. period. Yen-Su succeeded in rediscovering this secret, constructed a South-Pointing Chariot and left the specification for posterity, together with a history of their use, which he addressed to the Emperor of his day, verifying at the same time the actual two stories of B.C. 2698 and B.C. 1115."

Yen-Su described himself as being of the " Board of Works '. His specification is dated A.D. 1027.

It would be interesting to know if anywhere in China an actual chariot is still in existence.

In reconstructing the South-Pointing Chariot the conditions to be satisfied are:

1. That if the chariot deviated a given number of degrees from the straight course in one direction, the figure must deviate the same number of degrees in the opposite direction.
2. That the function must be reversible, that is, operate with equal accuracy, whether the deviation be to the right or to the left of the straight course, and also must function accurately with any number of degrees of deviation.

A little thought convinced me that the principle involved the use of what we engineers know as the differential gear.

Most of you who drive or use motor cars know that there is a mechanism in the back axle called a " differential " gear.

So far as we know, this mechanism was first used in this country about sixty years ago in the driving axle of pedal tricycles, and its invention, or at any rate its application to the axle of tricycles, has been attributed to Mr. Starley, who was a pioneer designer and maker of cycles.

In my young days it was always referred to as " Starley gear ".

It has been a feature of motor vehicles from their inception.

Its object is to permit one wheel to run faster than the other when turning corners, which is of course necessary, as when turning corners one wheel (the outer one) has to travel farther than the other (the inner one) in the same time.

Now if this deduction is correct, such a mechanical device must have been known to Chinese engineers at the period given by Dr. Herbert Giles.

I therefore set to work on this line, and was able to produce a rough model made from Meccano parts in time for my friend Dr. Kramer to use for demonstration in his lectures.

I subsequently constructed another model, which I conceived might have some resemblance to that which engineers, with their limited resources about 2600 B.C., might have built. This model I have here for demonstration.

Those who are interested in the chariot as an engineering problem may also be interested in the process of its evolution. At the same time, for those who are not engineers, I will try to explain in simple language how I arrived at the result which you see in the model.

Having established that the pointing figure must be controlled by what I have already endeavoured to explain as a differential gear, it was obvious that the pole (or what engineers would call a shaft) carrying the pointing figure must be attached to the small toothed wheel that is held between the two larger wheels, both of which

can turn round without hindrance on the " pole ", and when the chariot is moved in a straight line one of these two wheels must rotate in one direction, say clockwise, and the other at an equal speed contra-clockwise.

If this were not so the figure would turn away from the predetermined direction, and would therefore fail to act as a guide.

The next step was to decide on the train of gears which transmit the motion from the road wheels to the two toothed wheels that control the pointing figure.

If the road wheels (which must be equal in size) are set apart a distance equal to their diameter, it follows (by a law which we engineers know as the $\pi 2r$ law) that if one road wheel is held stationary (as a pivot) and the other road wheel is turned one complete revolution, the chariot will have changed its direction 180 degrees, or half a circle.

Under these conditions, if the two trains of gears are precisely alike, and they do not increase or reduce the amount by which the two wheels which control the pointing figure turn, it follows that the pointing figure will also turn half a circle.

It is of course necessary so to dispose the gears transmitting the motion that the figure makes its turn in the *opposite* direction to that of the chariot. This is a simple matter.

I do not claim that this is the only arrangement of gearing that will achieve the result, but I do claim that the problem cannot be solved without utilizing the differential gear, and this must be credited to Chinese engineers.

I regret to say I have no knowledge of Oriental history; but, if my solution is correct, and I see no other mechanical equivalent, it indicates that in the reign of the Yellow Emperor the Chinese had attained an astoundingly high degree of engineering knowledge and achievement, and discovered in 2600 B.C. or thereabouts a device which was rediscovered some 4,500 years later in Europe. Add to this the very high degree of scientific knowledge disclosed in such works as Mr. Honey's *Ceramic Art of China* and Mr. A. L. Hetherington's *Chinese Ceramic Glazes*, and one wonders what colossal catastrophe must have overcome a nation to obliterate for thousands of years such an advanced culture.

It almost suggests a devastation such as would destroy Western civilization if we were to be plunged into another war with all the horrors of the most modern destructive weapons.

ADDITIONAL NOTE

I have been asked to add something about the Chinese side of this subject as a footnote to Mr. Lanchester's extremely interesting and brilliant solution of the mechanical problem of how to make a carriage with a pointer which will always point in one direction however the carriage may twist and turn.

The sinologist's problem is quite different. There are stories, as has been seen, that the Yellow Emperor and Chou Kung both used south-pointing chariots; but, though such stories may possibly have some basis of tradition, we are not obliged to believe that such a vehicle or instrument was really used in the third millennium or even in the tenth or eleventh century before Christ. Huang Ti, or the Yellow Emperor, at best a vague figure in a vague antiquity, is now commonly regarded as a mythical culture hero, and scientific excavation shows that at the date assigned to him the Chinese had not emerged from the neolithic age. For the introduction of the south-pointing chariot into the story of Huang Ti's defeat of Ch'ih-yu we are apparently indebted to the *Ku chin chu*, a book no longer extant, by Ts'ui Pao of the fourth century A.D., or 3,000 years after the supposed event. The other story that Chou Kung in the tenth century gave such a machine to envoys of Yüeh-ch'ang comes from the apocryphal *Chou chi*. Both stories are found in or slightly before the Han (Huang Ti in *Shih chi*, Chou Kung in *Shang shu ta chuan*), *but without the south-pointing chariot*; and as late as the sixth century the *Sung shu*, c. 18, fol. 2, attributes the invention to Chou Kung, not mentioning Huang Ti. However, there seems to have been a belief in the Han dynasty that such a contrivance was or had been in existence, though I have failed to find any contemporary record of this, and thenceforward it became the ambition of engineers, impelled by their own curiosity or by

imperial command, to find out how such a thing might be constructed. Several later writers attribute the first of these attempts to the ingenious Chang Hêng (78-139), but his design was lost at the fall of the dynasty eighty years afterwards. The thing was made again by Ma Chün. Ma Chün was conducting an argument in the presence of the Emperor with two officials who contended that the south-pointing chariot had not existed in antiquity. Ma said at last, " An experiment would be worth more than all our arguments "; whereupon the Emperor told him to make such a chariot, and he made it. This must have been about A.D. 230, and the story (for my knowledge of which I am indebted to Professor Haloun) is found in a fragment of the *Fu tzŭ*, by Fu Hsüan (A.D. 217-278), which is most fully recorded in the *Ch'üan chin wên*, c. 50, fol. 10. Neither in the original text nor in the early comments is there any allusion either to Huang Ti or to the alleged recent invention by Chang Hêng; nor, indeed, is the south-pointing chariot mentioned in the long biography of Chang in *Hou han shu*, c. 89. One commentary does however refer to the *Kuei ku tzŭ* (? c. 300 B.C.), which says, " When the people of Chêng collect jade they must take a south-pointing carriage so as not to miss the way "—and this, if genuine, would seem to be the earliest reference to the contrivance found as yet. Then Yao Hsing had one made at Ch'ang-an (Hsi-an), but when Wu Ti (420-423) captured the place the chariot was found, by one account, with no machinery inside it. About the year 479 Tsu Ch'ung-chih made a chariot which is described as having been a great success, and the mechanism was of bronze. According to the *Nihongi* the Chinese monk Chih-yu presented a south-pointing chariot to the Emperor of Japan in 672. In the eighth century the *T'ang liu tien* devotes some space to the vehicle as a normal part of the Emperor's retinue; but yet we are told that in 815 the Emperor inspected a newly made specimen at his capital, apparently as a curiosity.

No actual specification, or even general description of how the thing worked, before the eleventh century has survived; and then, in December 1027, Yen Su presented to the Throne a specification which is recorded in detail in the official history. The construction was very simple, and consisted of five cogwheels—a large horizontal wheel in the middle to control the upright shaft and pointer; two vertical wheels, one fixed concentrically on the inside of each of the road-wheels; two small horizontal wheels, one on each side, to mesh with the vertical wheels and with the large middle wheel; and finally two little wheels of undefined purpose. The diameters of the wheels, the numbers of cogs, and the motions of the wheels when in action are all correctly given, but the specification is obviously incomplete. Fortunately the gaps may be filled from a second more elaborate and partly unintelligible specification presented in 1107 by Wu Tê-jên. From this we learn that the two flat cogwheels were " rise-and-fall wheels ", that is to be lifted out of or dropped into gear, that they were weighted with iron, and controlled by cords of twisted bamboo which passed over the " little wheels ", which are defined as pulleys or rollers " without teeth ". The way in which this primitive gear was worked is roughly indicated in the first specification, and the thing can be constructed, and would work within limits correctly, but in a very slow and cumbersome manner which, as Mr. Lanchester has pointed out, would render it absolutely useless for travelling. But then in historical times the south-pointing chariot did not travel. It was used only as an ornamental piece in the imperial processions, which went at walking pace no great distances along streets which were often straight. When, only twenty years after the second extant specification had been presented, the Court was compelled hurriedly to " migrate to the south " the south-pointing chariot was not invited to lead the way; and never since that date has it appeared in the list of the State coaches. An illustrated encyclopædia (*San ts'ai t'u hui*, 1607) gives a reduced drawing of the pointer with a note (both drawing and note taken without acknowledgment from *Ku yü t'u* by Chu Tê-jun, 1341) to say that it had been seen in the collection of the well-known writer Yao Sui (1239-1314), and that it was made of jade. The human pointing figure stands on the head of the monstrous Ch'ih-yu.

It will thus be seen that there is no real record of such a machine having been made before about A.D. 230, and no indication that the Chinese did, though no doubt no proof that they did not, find and lose the principle of the differential gear during the thousand years of their mechanical efforts.

No early Chinese writer seems to have associated the magnetic needle with the south-pointing chariot, and the question of the discovery of the needle is not affected one way or the other by the story of the chariot.

In *Adversaria Sinica*, 1909, pp. 219-222, Professor H. A. Giles translated the first specification, from *T'u shu chi ch'êng*, xxxii, c. 171, but failed to understand it. The text of both specifications was printed in the *T'oung-pao*, 1924, pp. 83-98, with translation, notes, and diagrams. See also *Sung shu*, c. 18, fol. 2; *Sung shih*, c. 149, fols. 6, 7; *San ts'ai t'u hui*, vi, c. 5, fol. 10; *Ch'üan chin wên*, c. 50, fol. 10; *Ho han san ts'ai t'u hui*, 1712 (ed. 1906), p. 405.

I am indebted to my friends Professors Gustav Haloun and Perceval Yetts for help in some bibliographical and archæological details.

A. C. M.

APPENDIX BY GEORGE LANCHESTER

The Rev. A. C. Moule has kindly sent me a rough summary of an article by Mr. Liu, to which I would like to make the following reply:

It is evident that in the absence of a diagram of the mechanism which I have employed in my solution of the South-Pointing Chariot, Mr. Liu has misunderstood how and where the differential gear is employed. I therefore enclose a supplementary diagram, annotated to clarify this point.

Since all descriptions or specifications recorded were evolved some 2,000 or 3,000 years later than the South-Pointing Chariot of Huay-ti legend, I submit the possibility that they may bear no resemblance to the specification of the original, and can only be regarded as suggested solutions, neither can they be accepted as authentic descriptions of the Huang-ti nor of the Chou Kung South-Pointing Chariots.

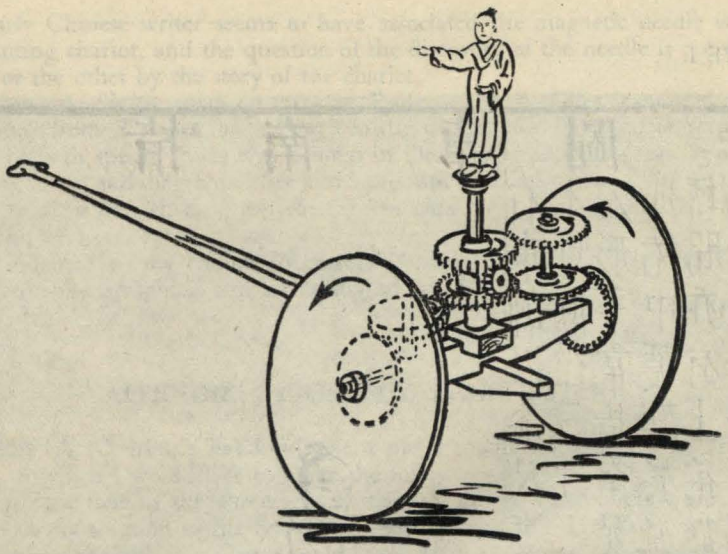
Mr. Liu says that there exist historic records stating that "there have been 133 men who have worked at the S.P. Chariot, of whom 8 succeeded and 5 failed".

I maintain that unless the S.P. Chariot does not *automatically* control the Pointing Figure it cannot be acceptable as successful.

PLATE I.

A POINTER FROM "SAN TS'AI T'U HUI".

PLATE II.



THE SOUTH-POINTING CHARIOT, 2698-2598 B.C.

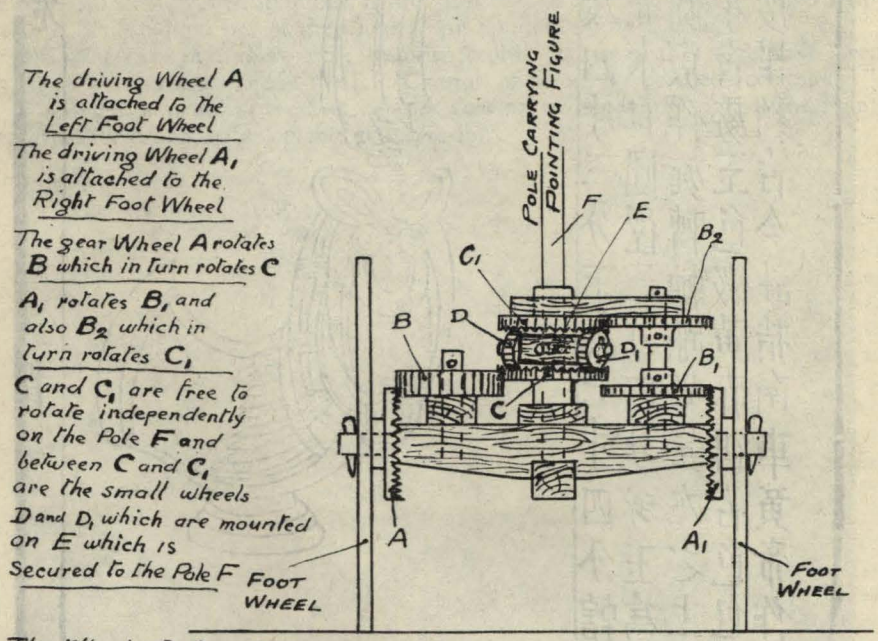


DIAGRAM OF MECHANISM OF THE SOUTH-POINTING CHARIOT.

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